

# Using the 0.3-NA SEMATECH Berkeley MET for sub-22 nm half pitch development

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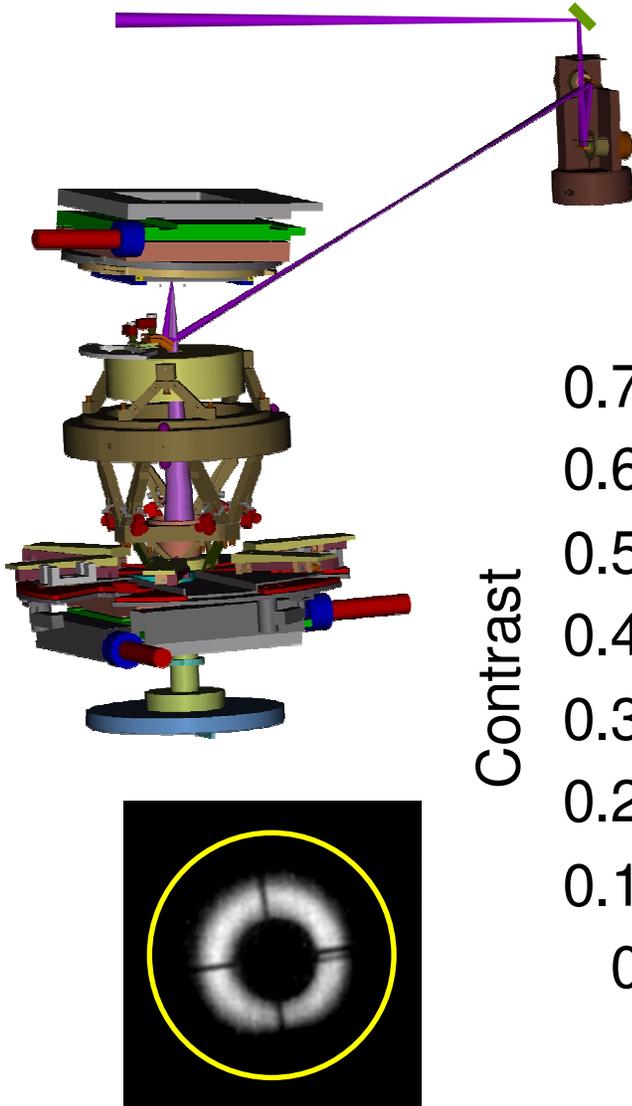
# Outline



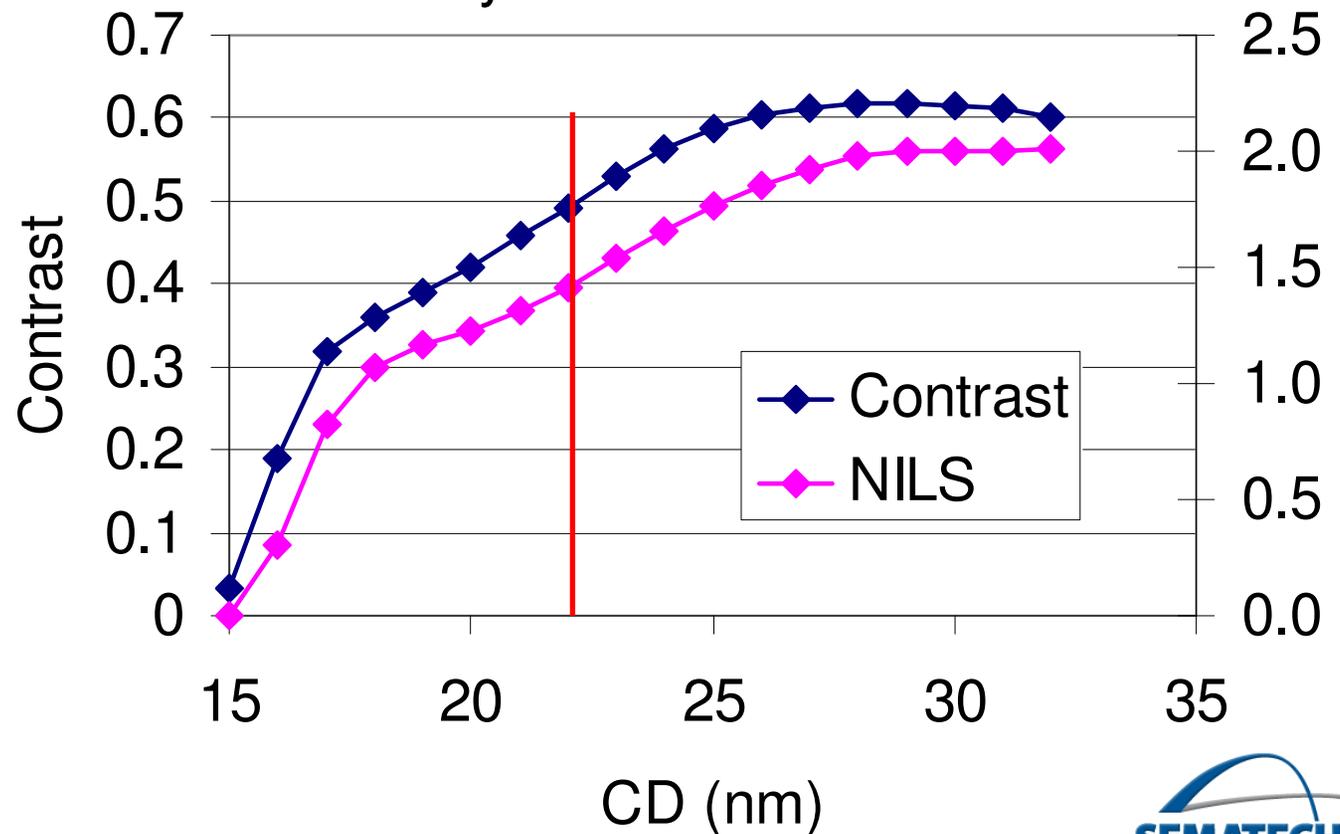
- Pushing the limits with source optimization
- Source optimization results
- Present mask resolution limits
- A pseudo strong PSM scheme (PS-PSM)
- PS-PSM results
- Resist hitting a brick wall?
- Mask-based printing improvements
- Future plans (0.5-NA MET)



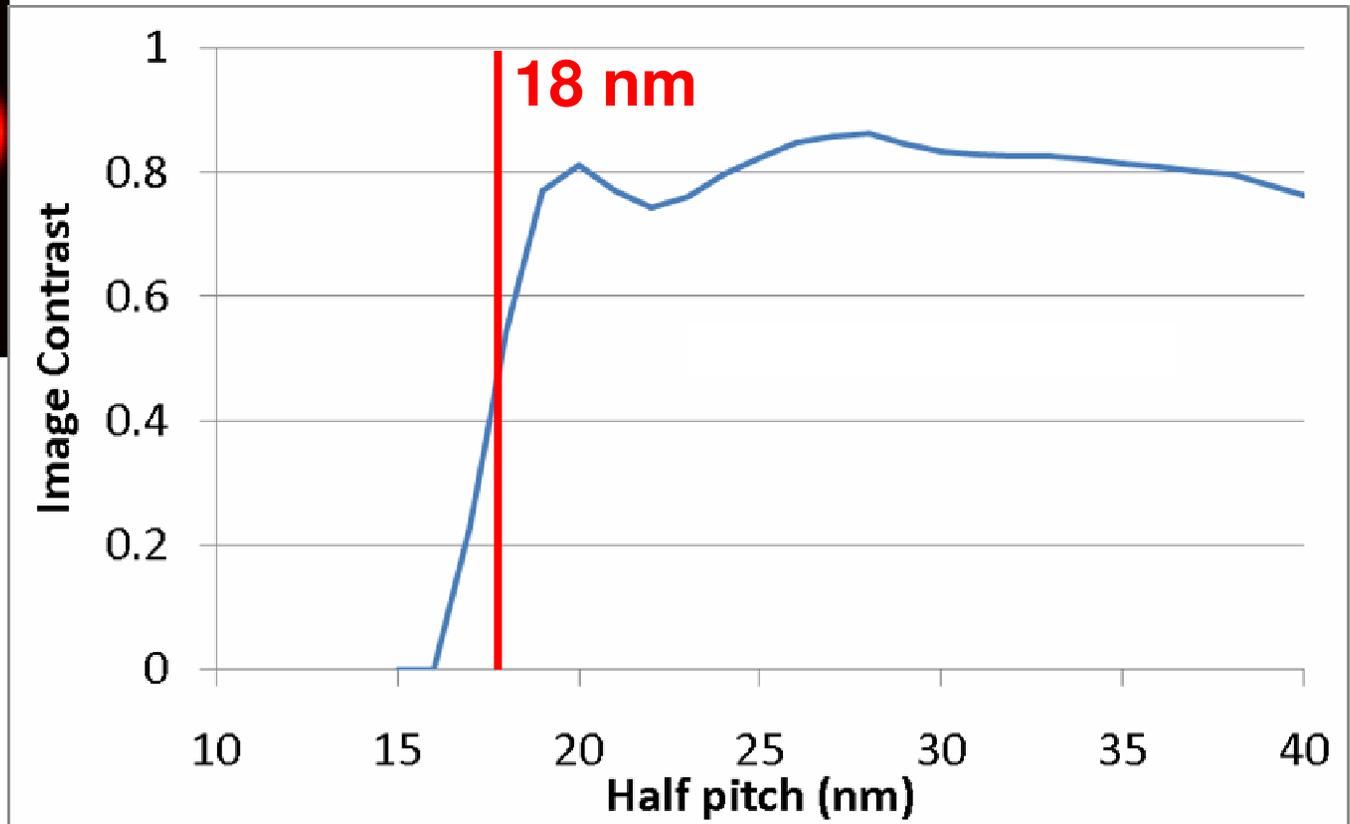
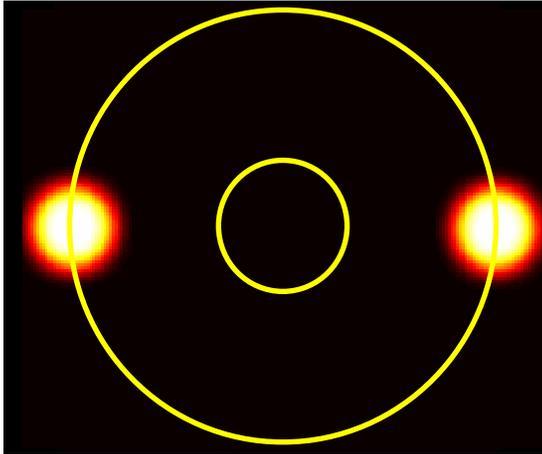
# 0.3-NA METs with conventional illumination have ~22-nm resolution limit



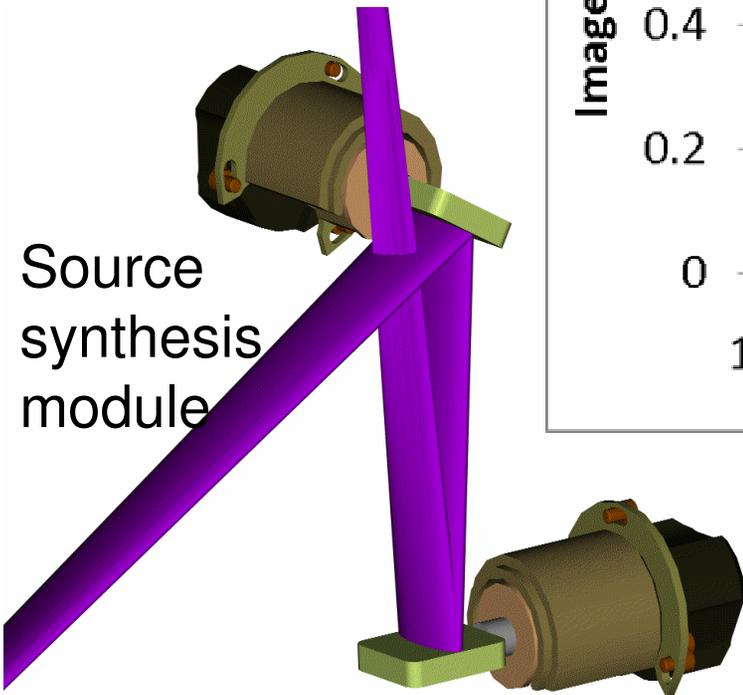
- 0.3-NA
- ~1-nm wavefront error
- 3% flare
- Annular illumination ( $0.35 < \sigma < 0.55$ )
- Binary mask



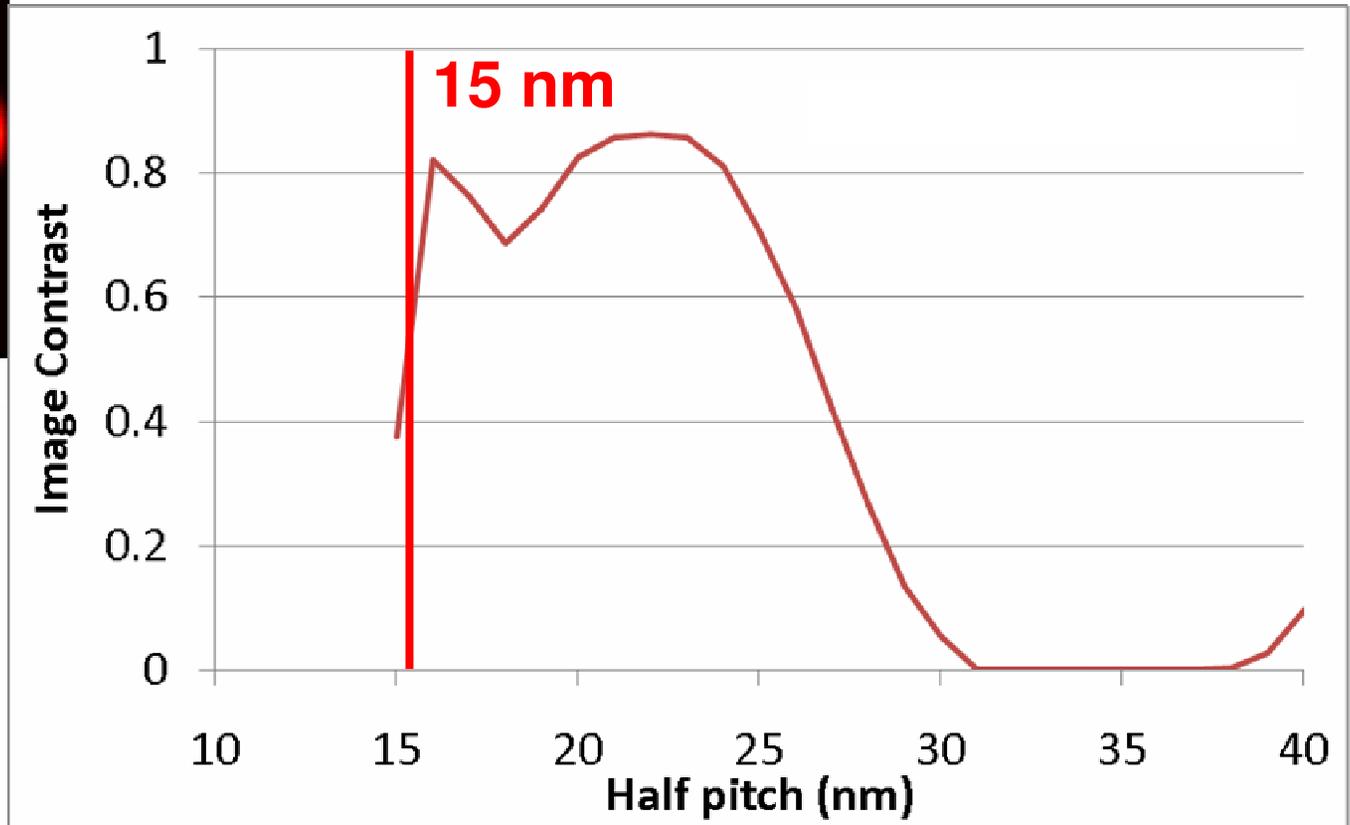
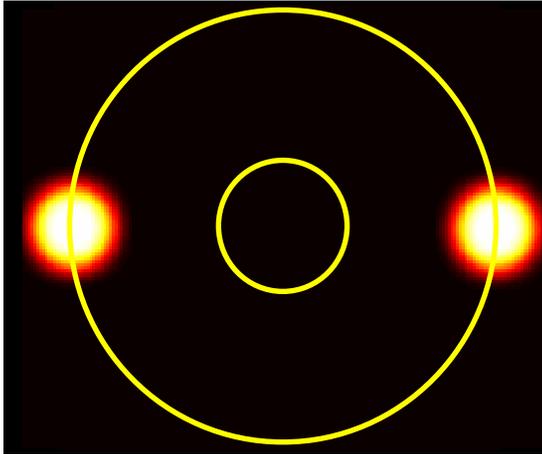
# Source optimization in the SEMATECH Berkeley MET enables ~12-nm resolution



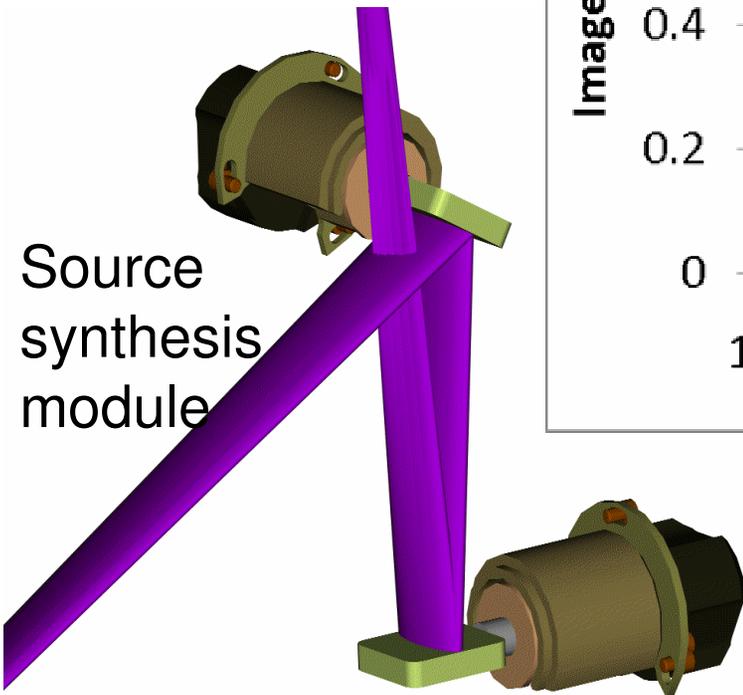
Source synthesis module



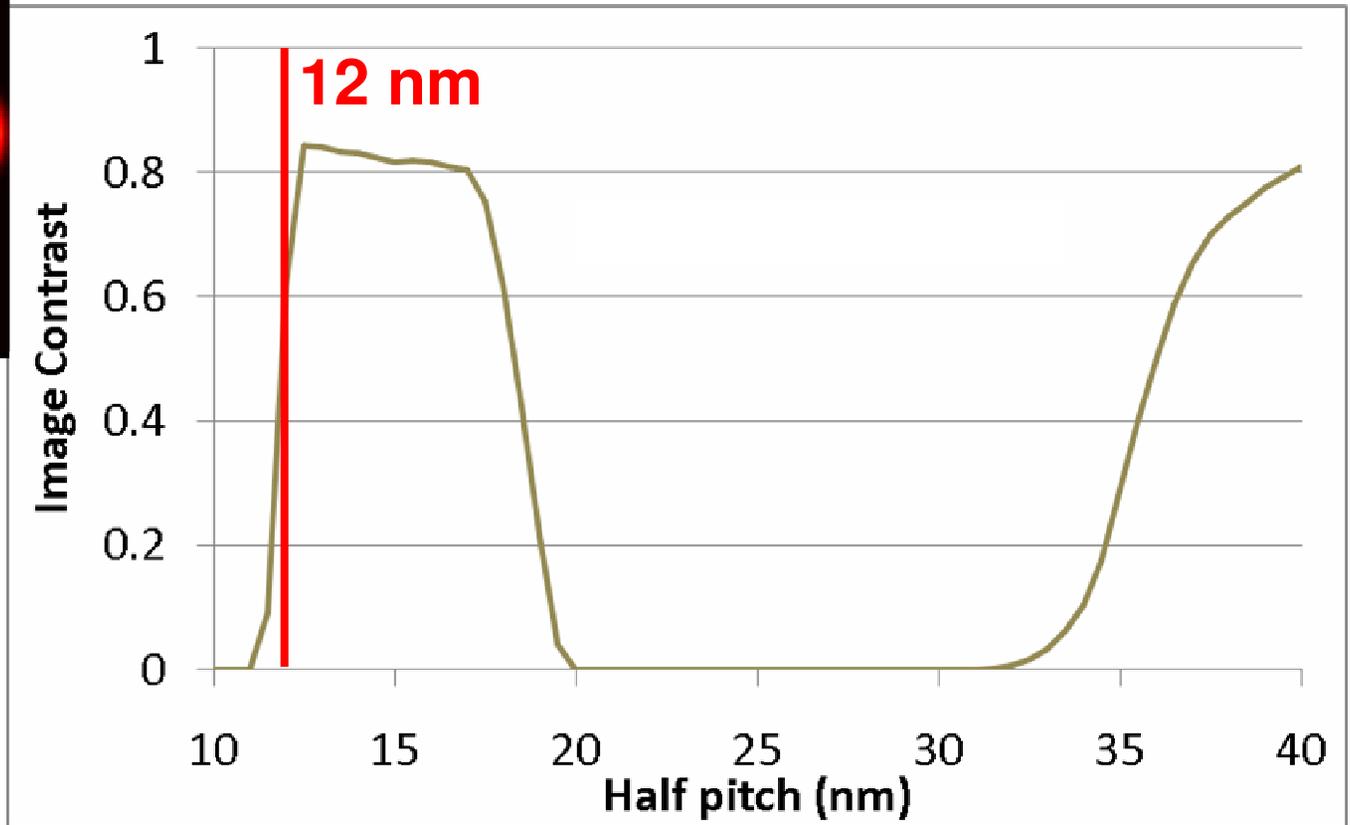
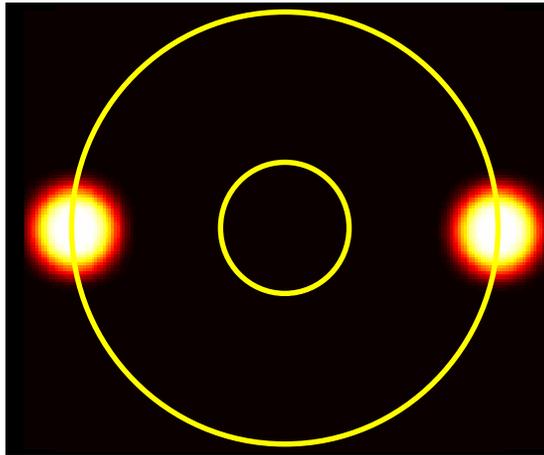
# Source optimization in the SEMATECH Berkeley MET enables ~12-nm resolution



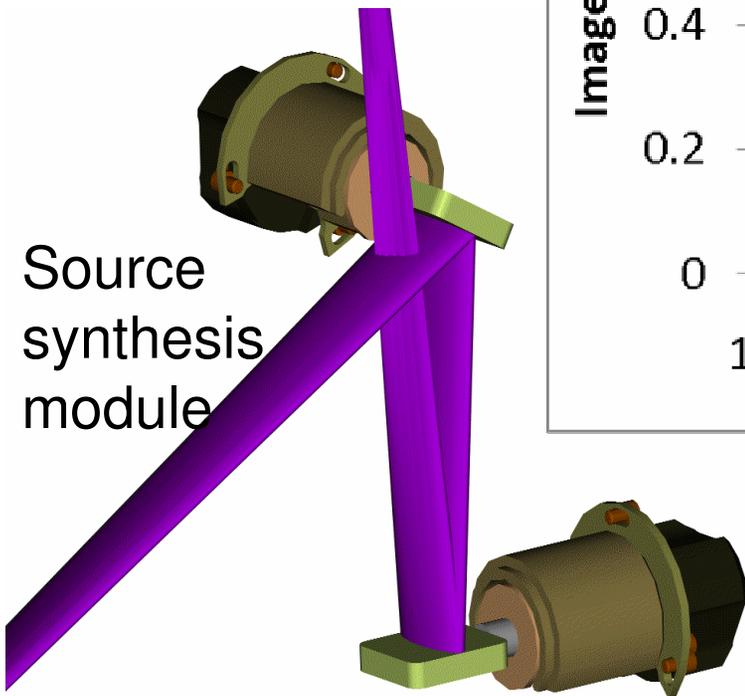
Source synthesis module



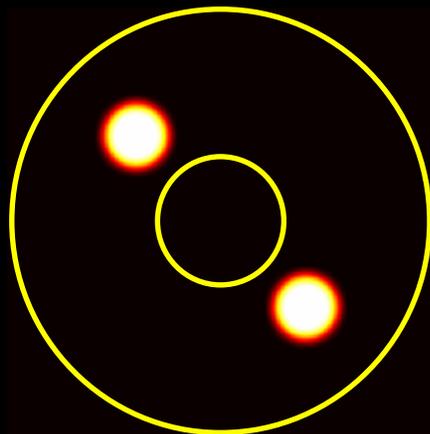
# Source optimization in the SEMATECH Berkeley MET enables ~12-nm resolution



Source synthesis module

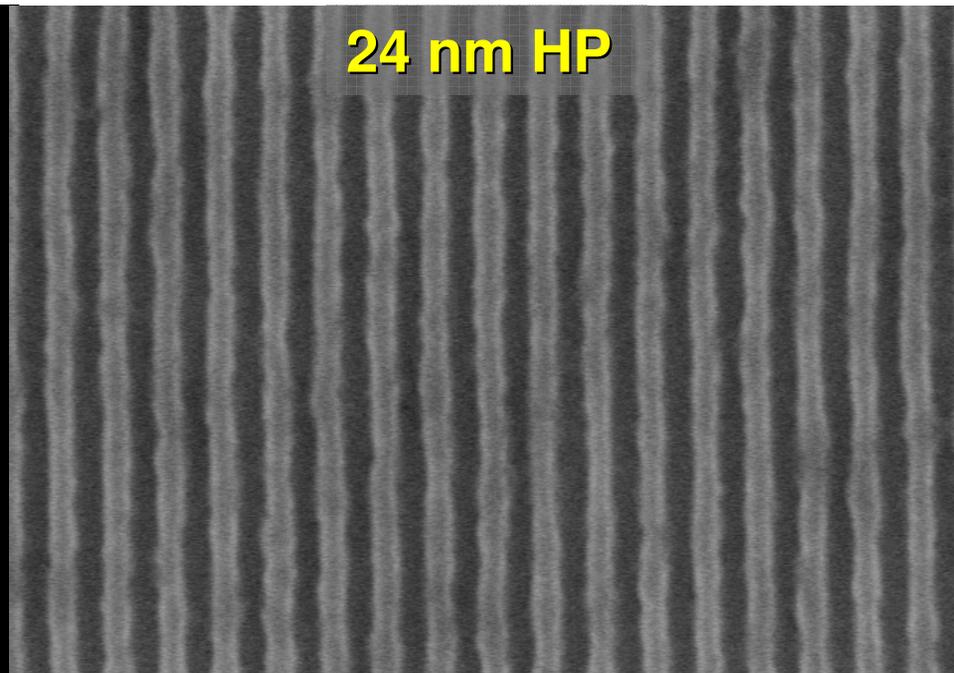


# 20-nm resolution achieved with source optimization



From 2008 EUVL Symposium

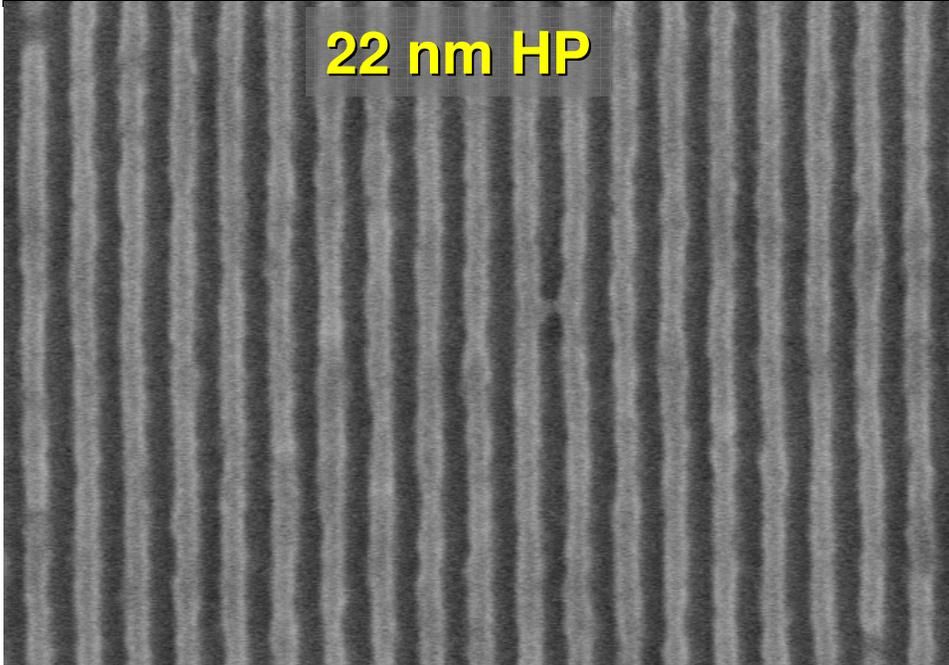
24 nm HP



S4800 2.0kV 4.2mm x150k

300nm

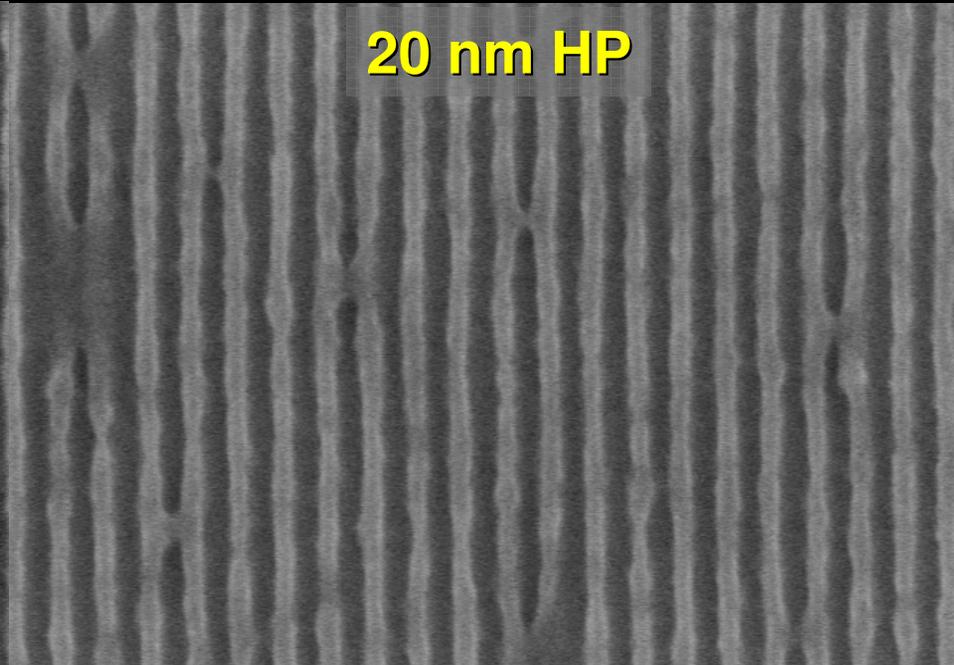
22 nm HP



S4800 2.0kV 4.2mm x150k

300nm

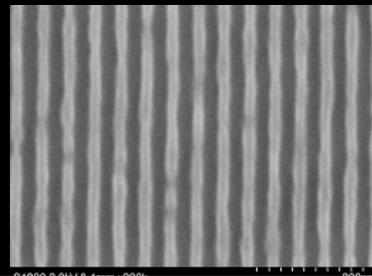
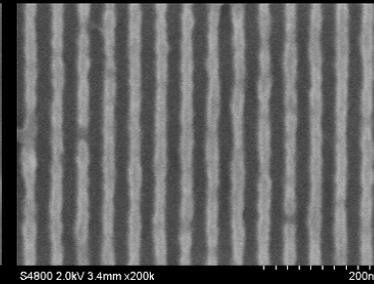
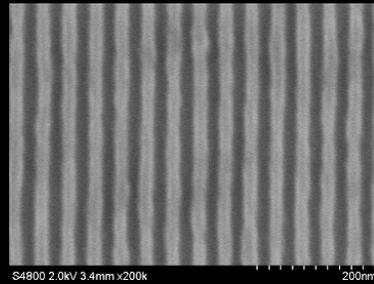
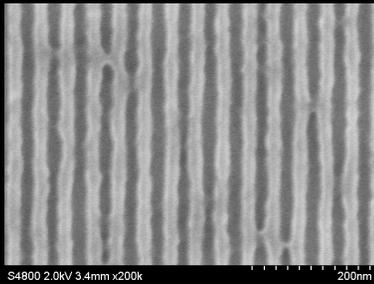
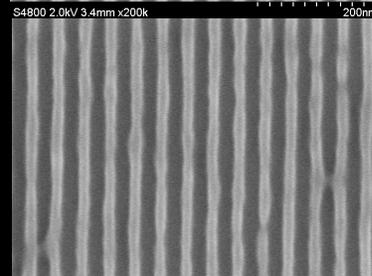
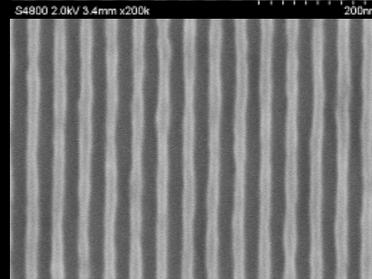
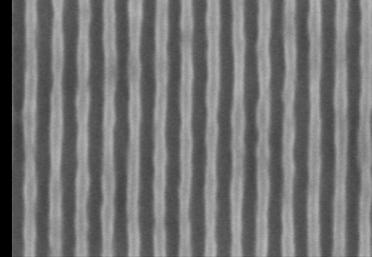
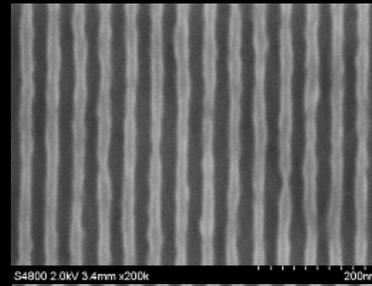
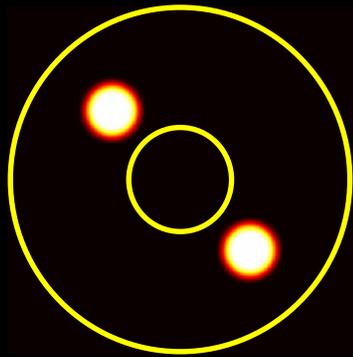
20 nm HP



S4800 2.0kV 4.2mm x150k

300nm

# *22-nm half pitch champion resist performance from 2008*



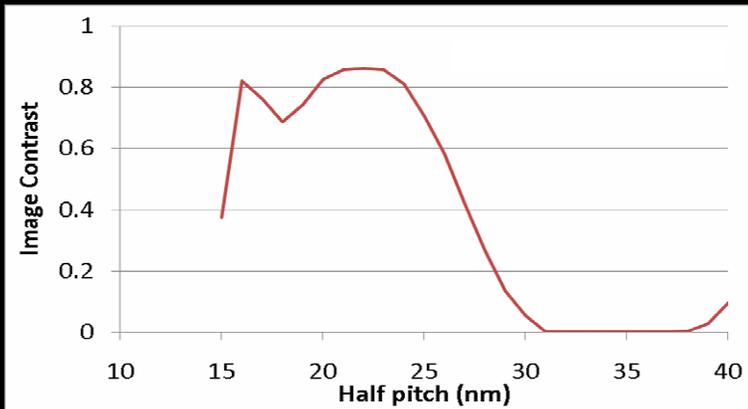
*200 nm focus range*

*From 2008 EUVL Symposium*

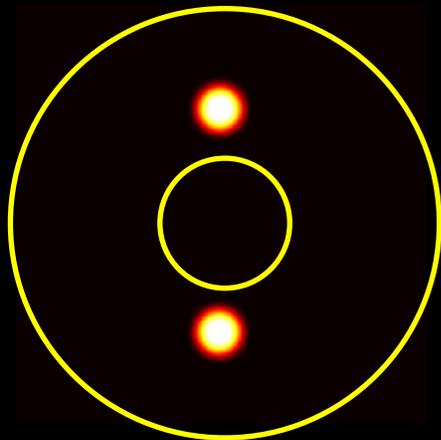
*16% dose range*



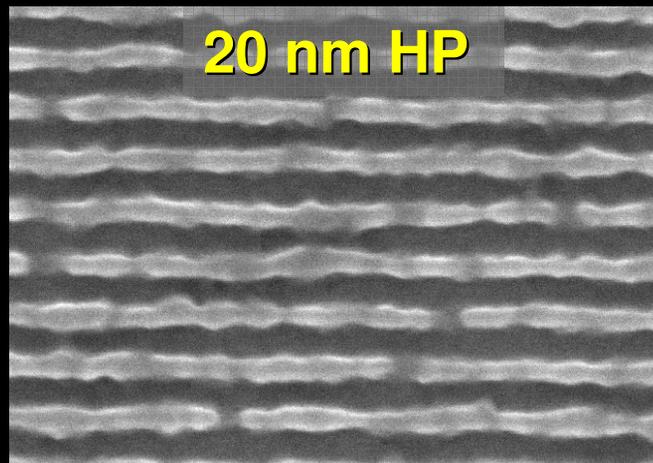
***2009: Trying to break the  
20-nm half pitch barrier***



***20-nm limit still observed with higher resolution illumination***

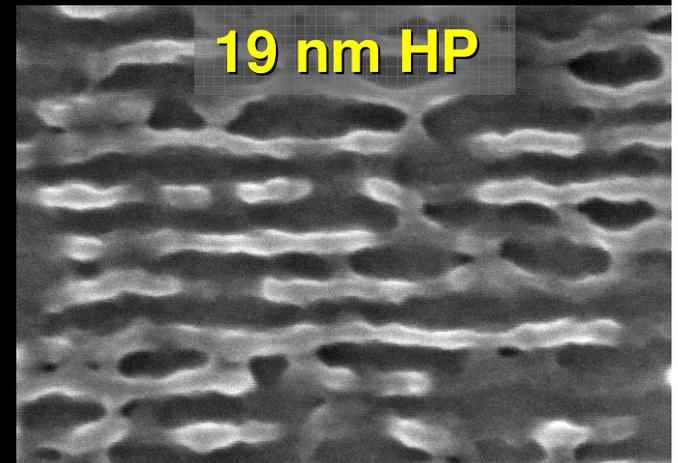


**20 nm HP**



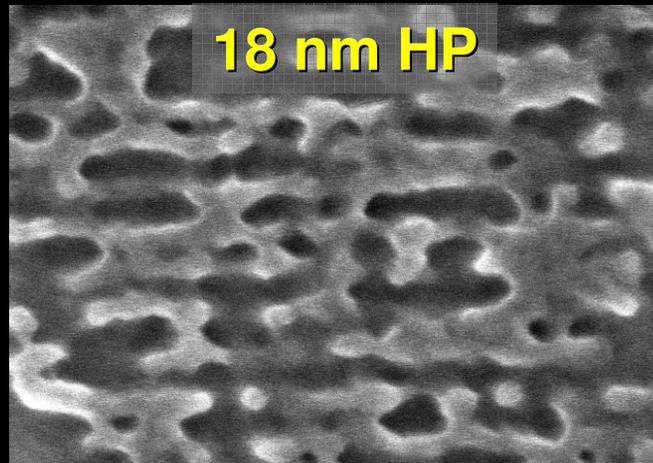
S4800 2.0kV 2.2mm x250k 200nm

**19 nm HP**



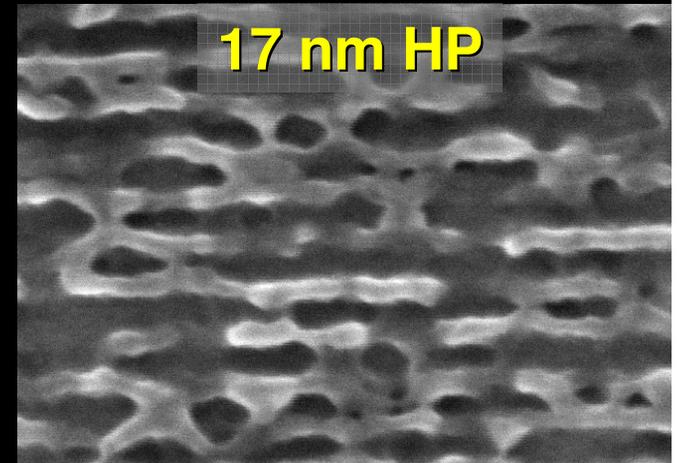
S4800 2.0kV 4.2mm x250k 200nm

**18 nm HP**



S4800 2.0kV 2.2mm x250k 200nm

**17 nm HP**



S4800 2.0kV 4.2mm x250k 200nm

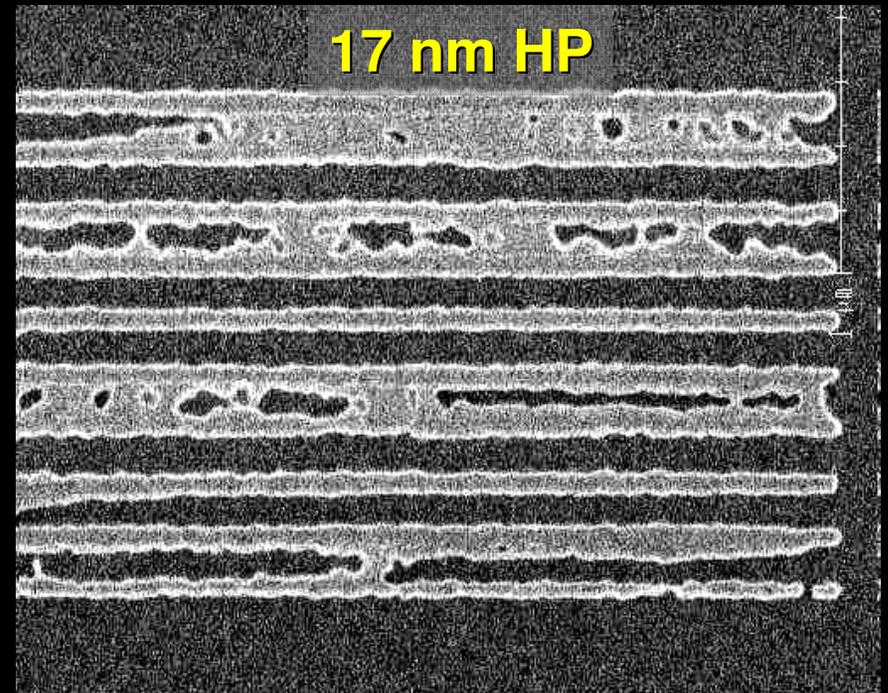
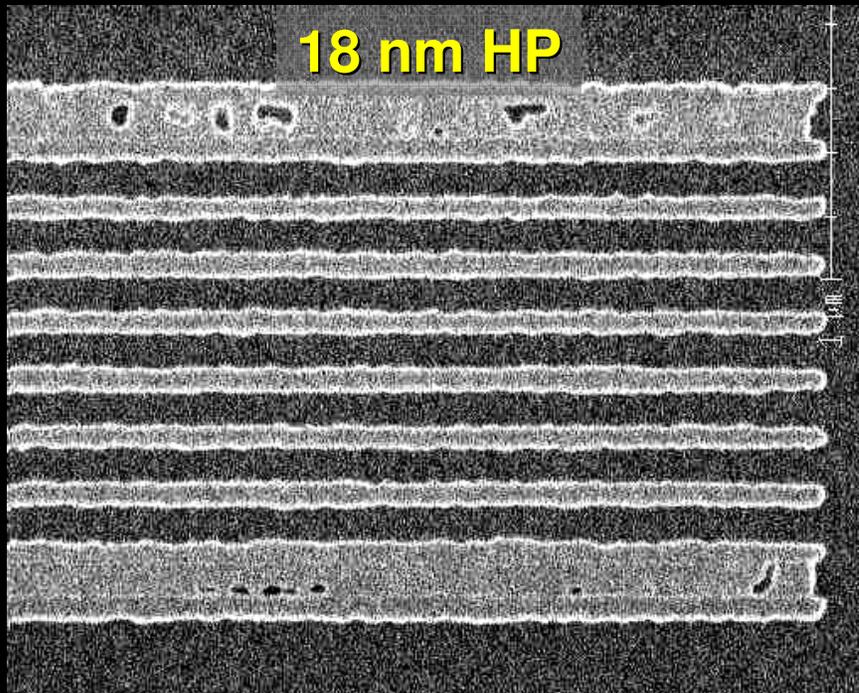
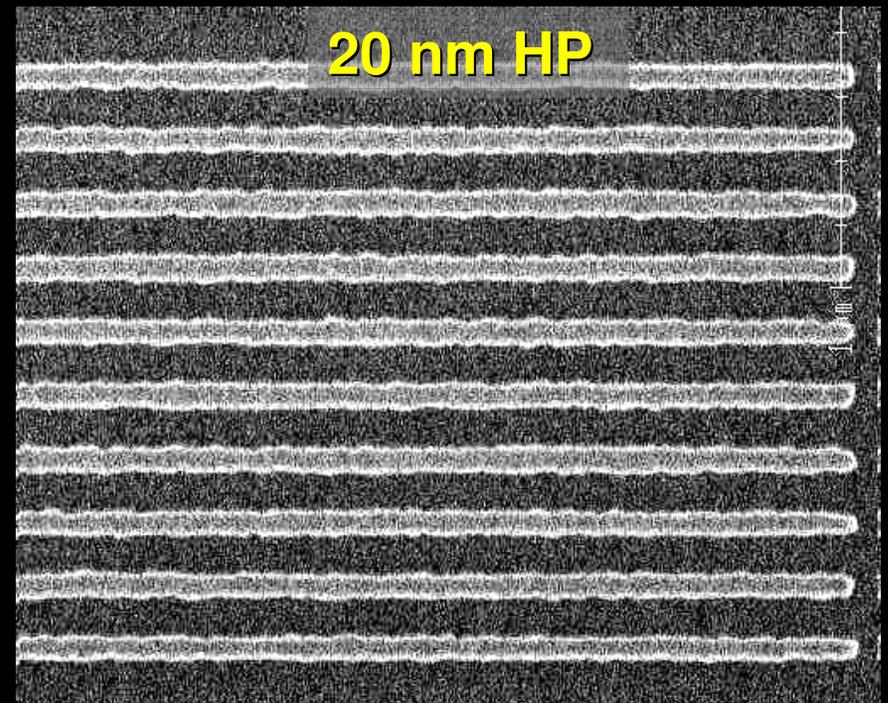


***Is mask or resist to blame?***

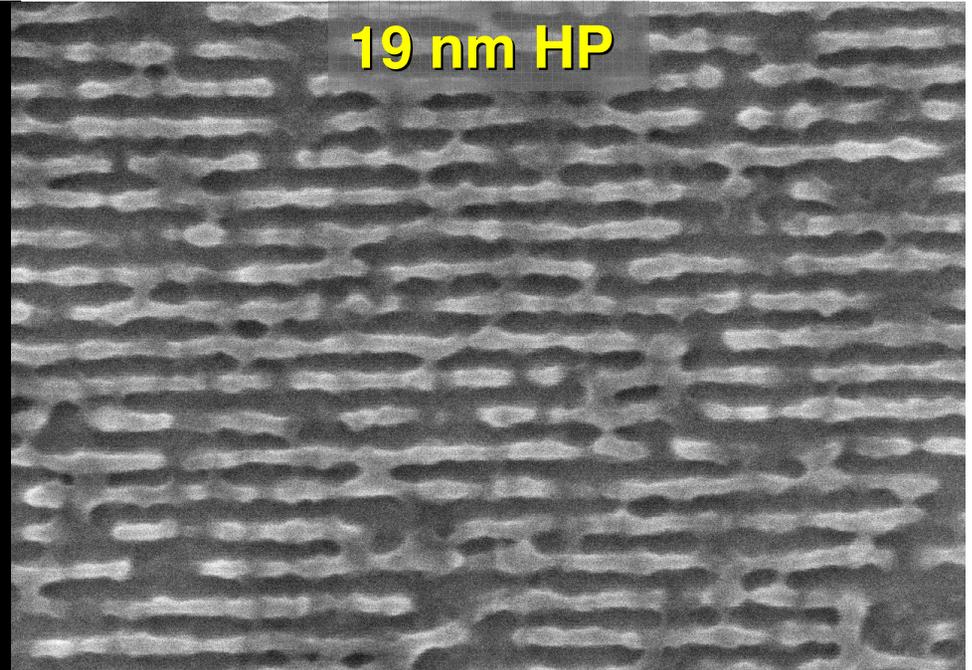
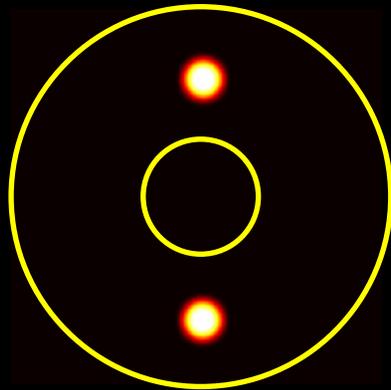
# *Three-year old SEMATECH Berkeley MET mask has 18-nm resolution limit*



Current mask  
making capabilities  
expected to be  
improved

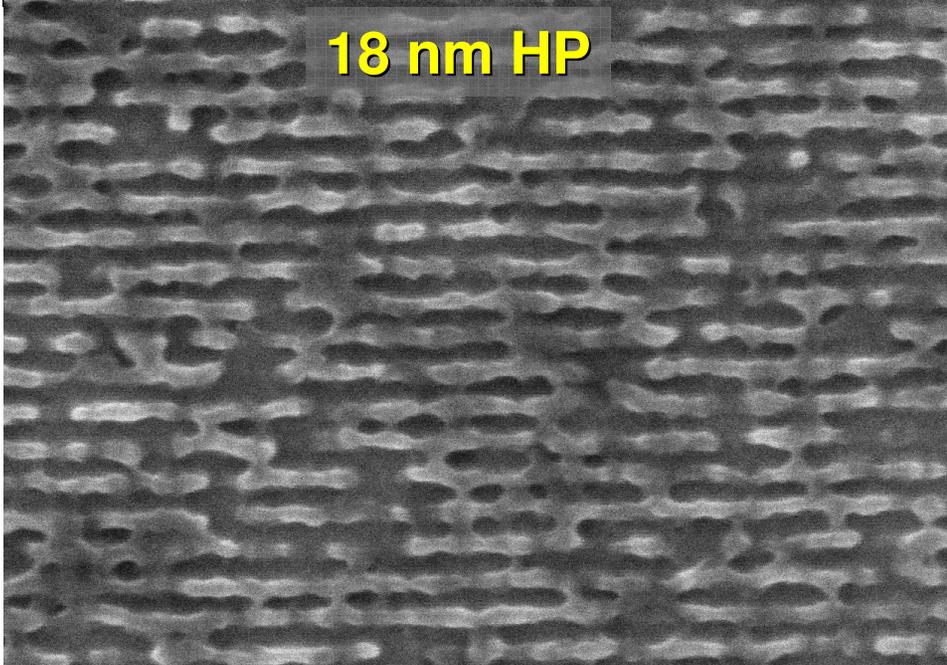


***New mask shows  
minimal improvement in  
printing performance***



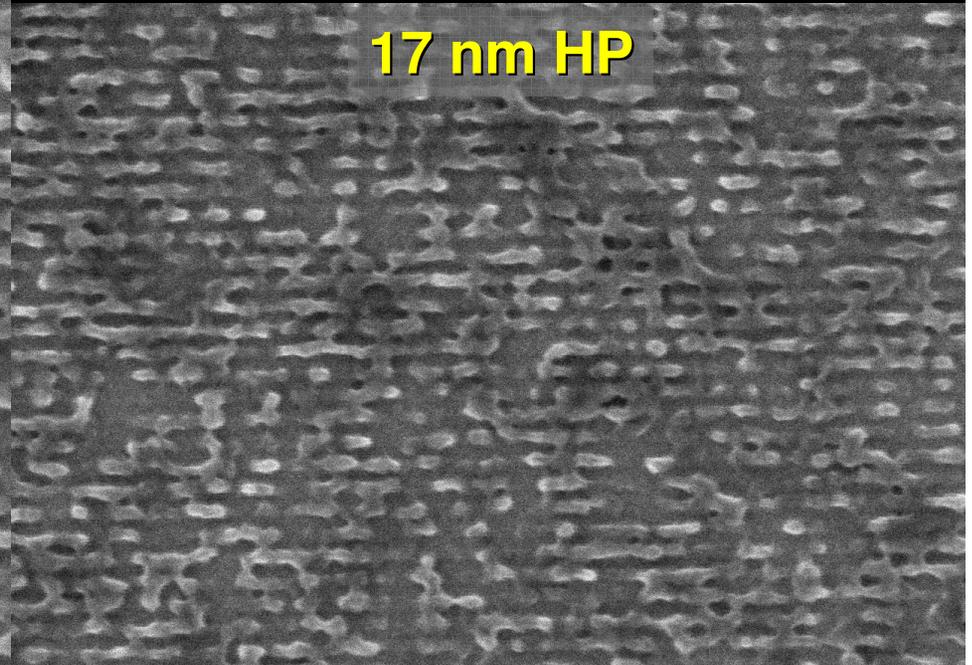
S4800 2.0kV 4.2mm x130k

400nm



S4800 2.0kV 4.2mm x130k

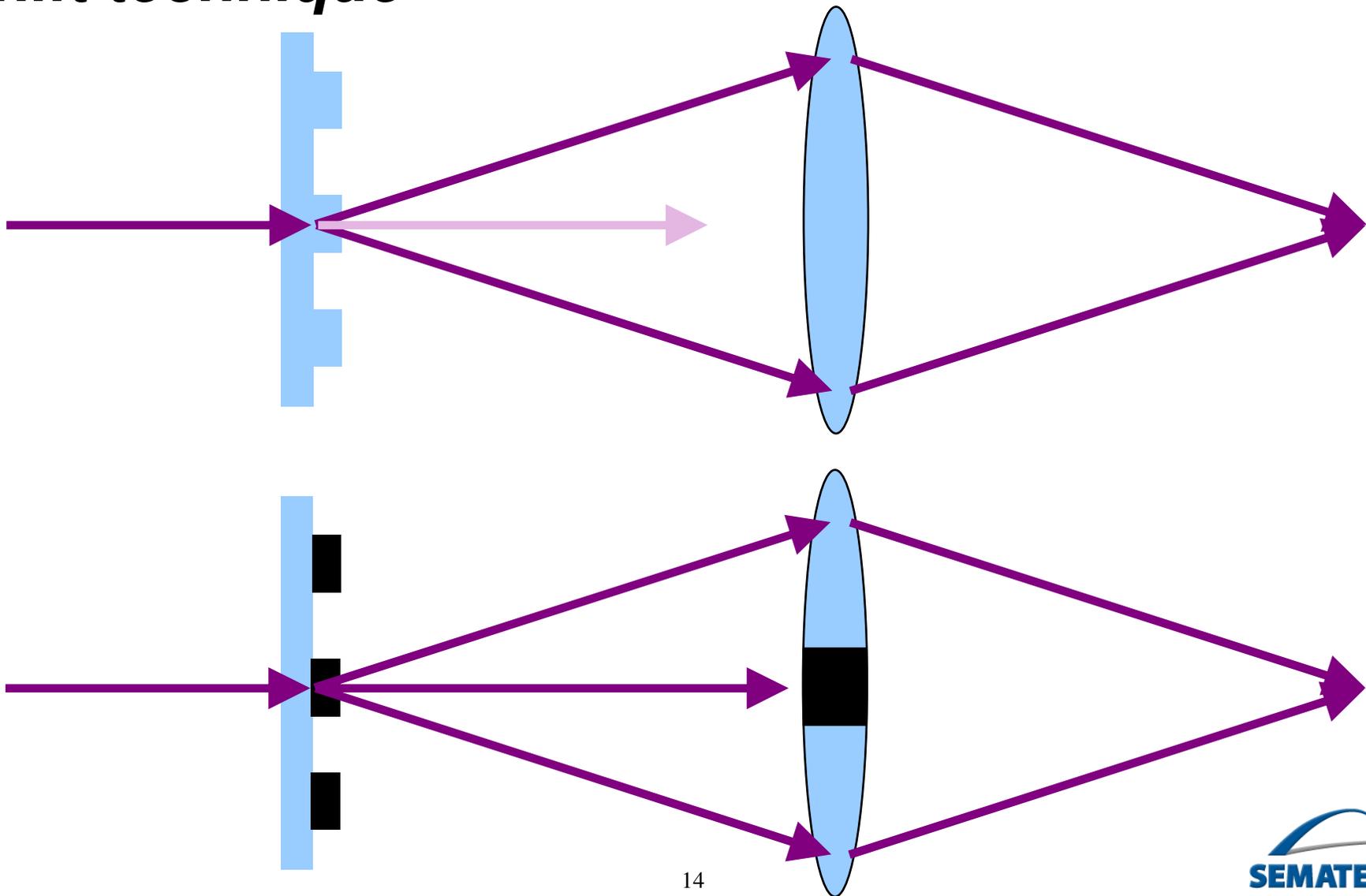
400nm



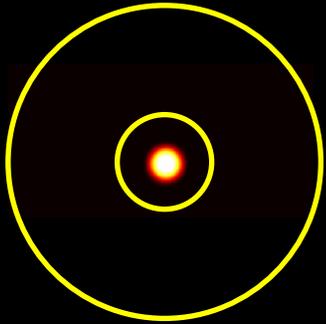
S4800 2.0kV 4.2mm x90.0k

500nm

# *Mask patterning limitations can be overcome with pseudo strong phase shift technique*

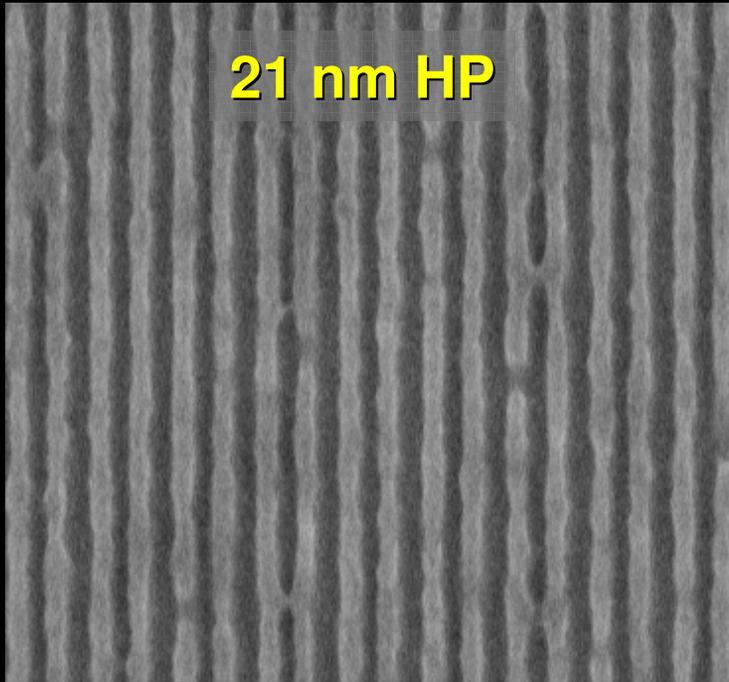


# *Resist limits remain evident below 20 nm*

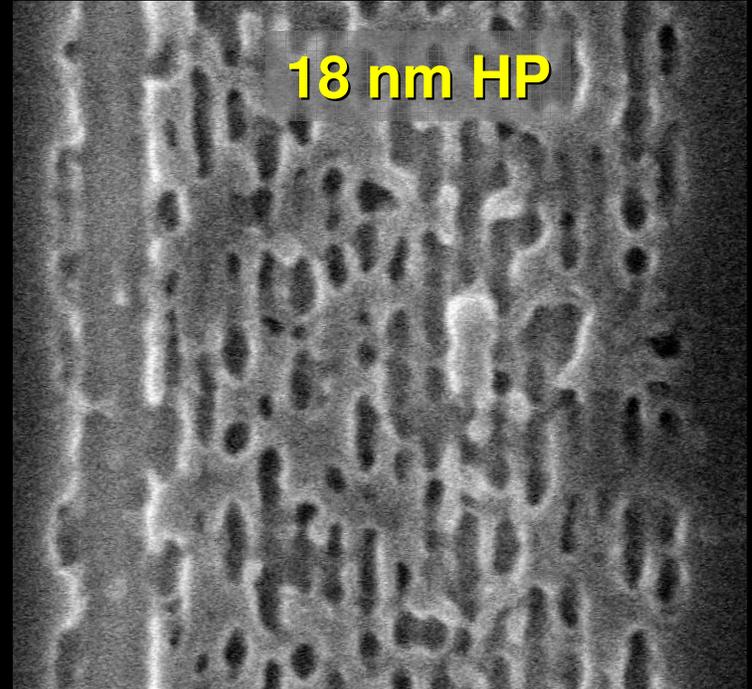


Pseudo  
PSM  
prints

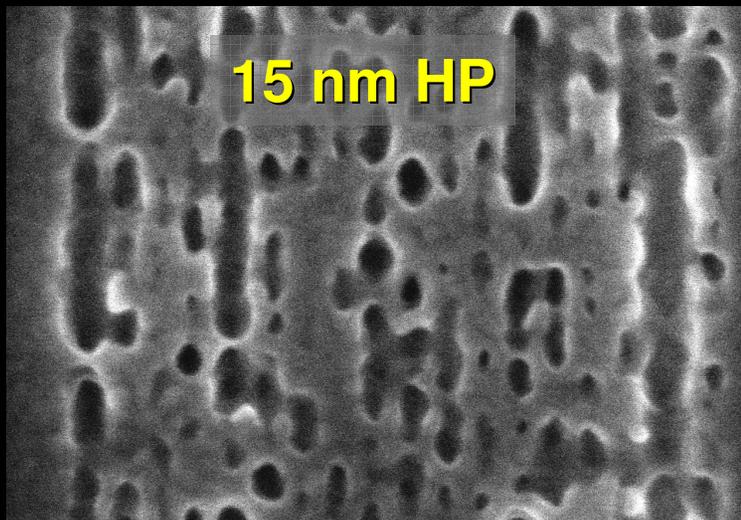
21 nm HP



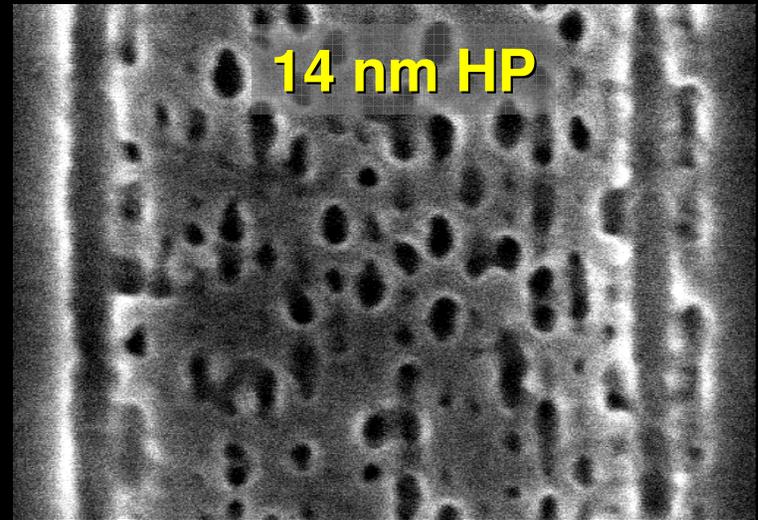
18 nm HP



15 nm HP



14 nm HP

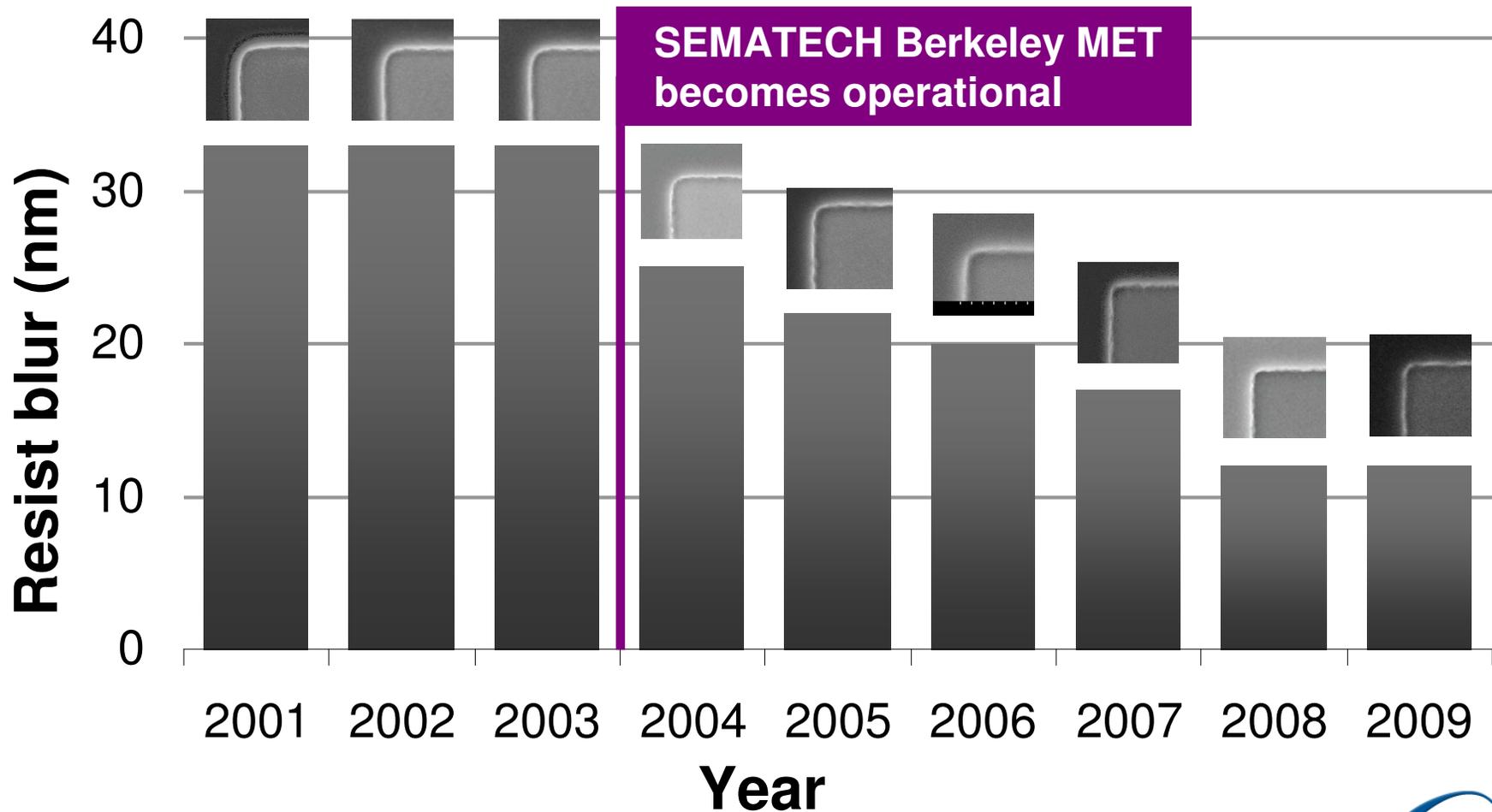


***Conclusion: we are resist limited***

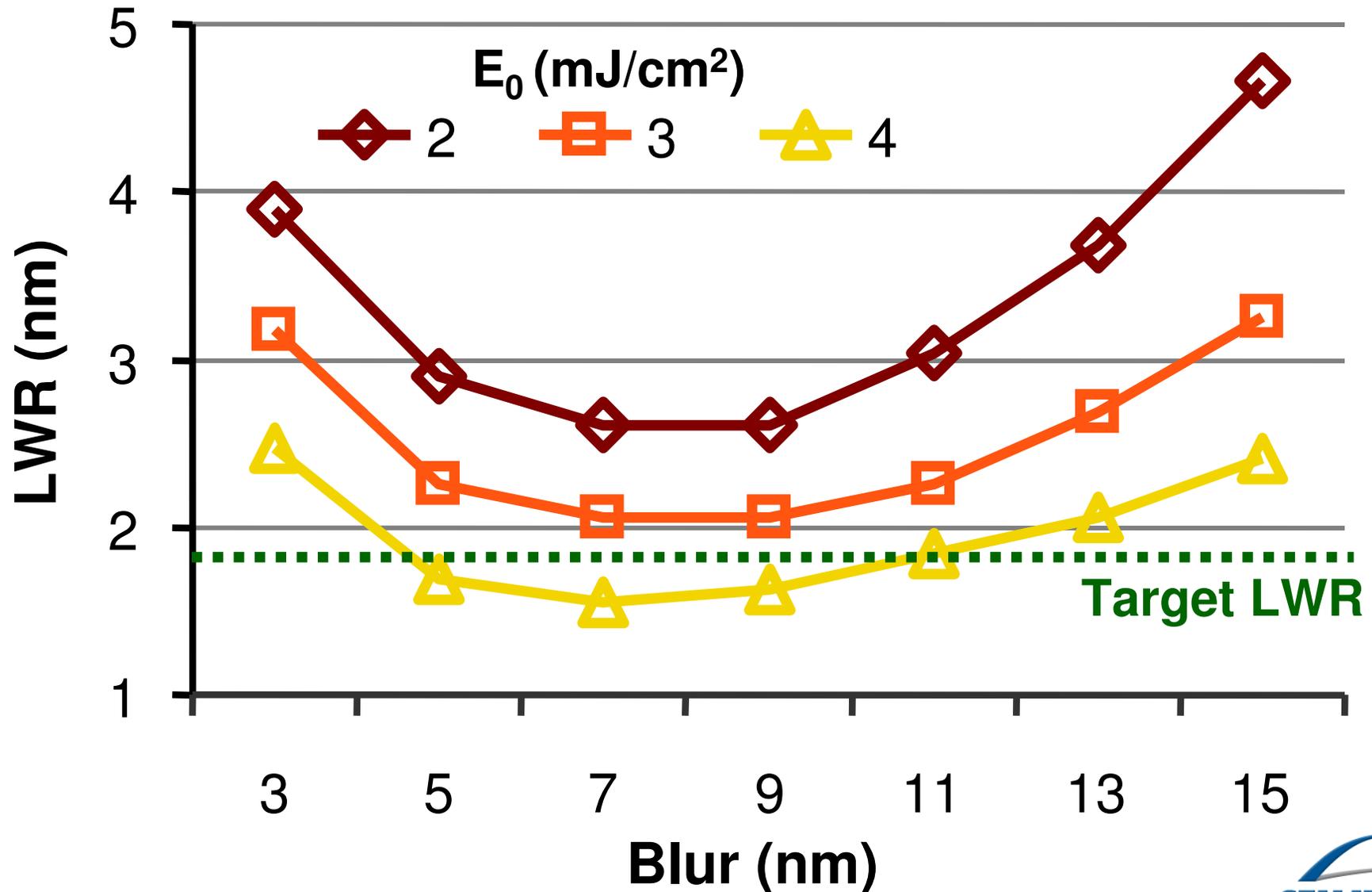
# Past year brings little improvement in resist resolution metrics



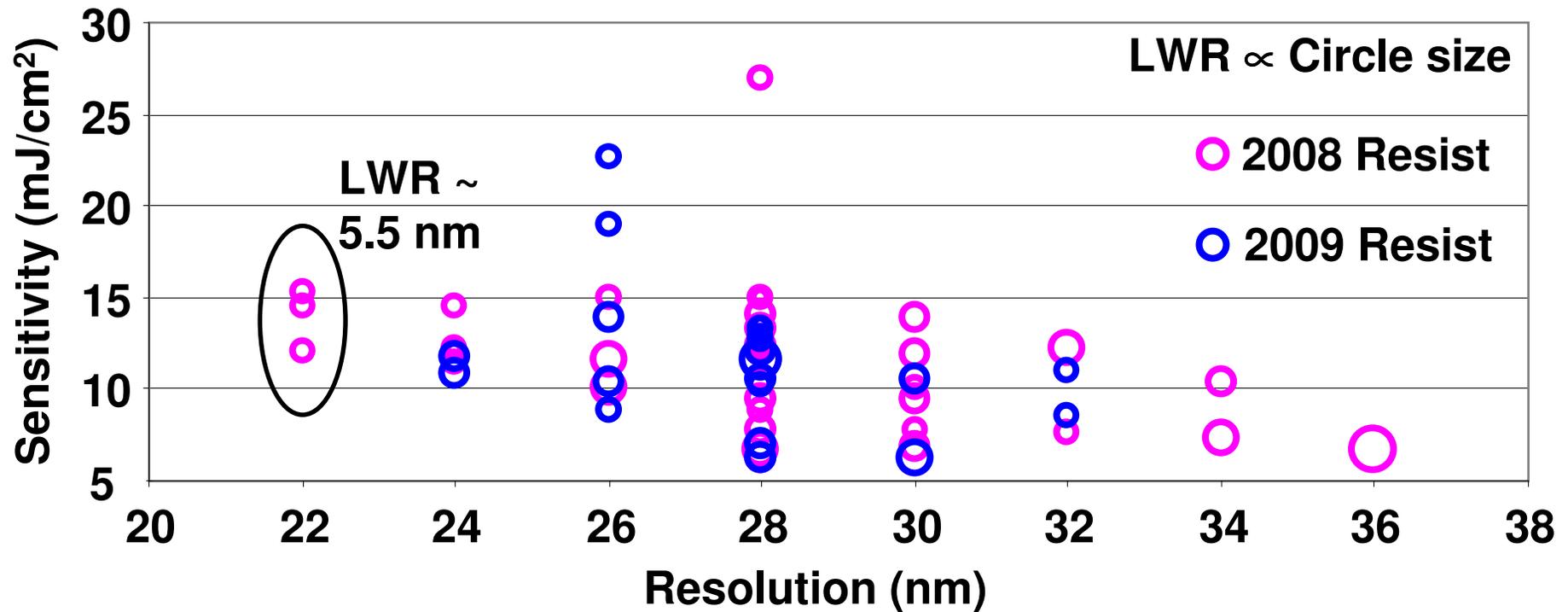
## Measured blur from past years' champion resists



# Stochastic modeling shows optimal blur for 22-nm half pitch to be 7-8 nm



# *RLS analysis shows minimal progress in champion resist performance in 2009*



- Little progress in RLS improvement in 2009
  - No improvement in champion resolution
  - Little improvement in LWR
  - Some progress in sensitivity

Data provided by  
Chawon Koh



***Mask-based help  
for the resist***

# Absorber thickness optimization improves effective resist resolution



SAMSUNG

Courtesy of Seong-Sue Kim and Hwan-Seok Seo, Samsung

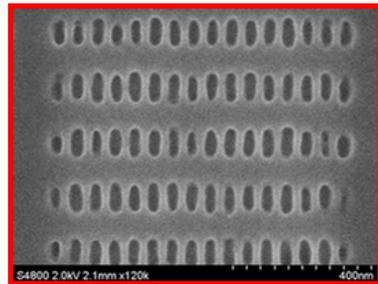
HP		38 nm	36 nm	34 nm	32 nm	30 nm	28 nm	26 nm
42.4 nm TaN	H							
	V							
52.4 nm TaN	H							
	V							
62.4 nm TaN	H							
	V							
82.8 nm TaN	H							
	V							



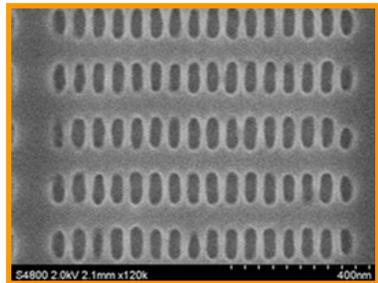
# OPC mitigates resist blur and improves 2D printing fidelity



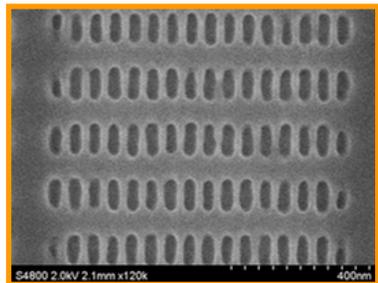
Courtesy of Tom Wallow,  
Global Foundries



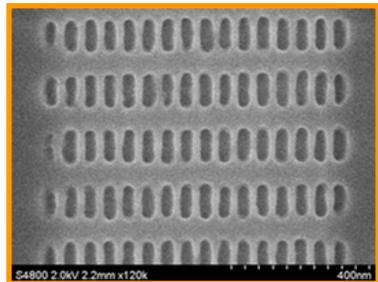
no  
OPC



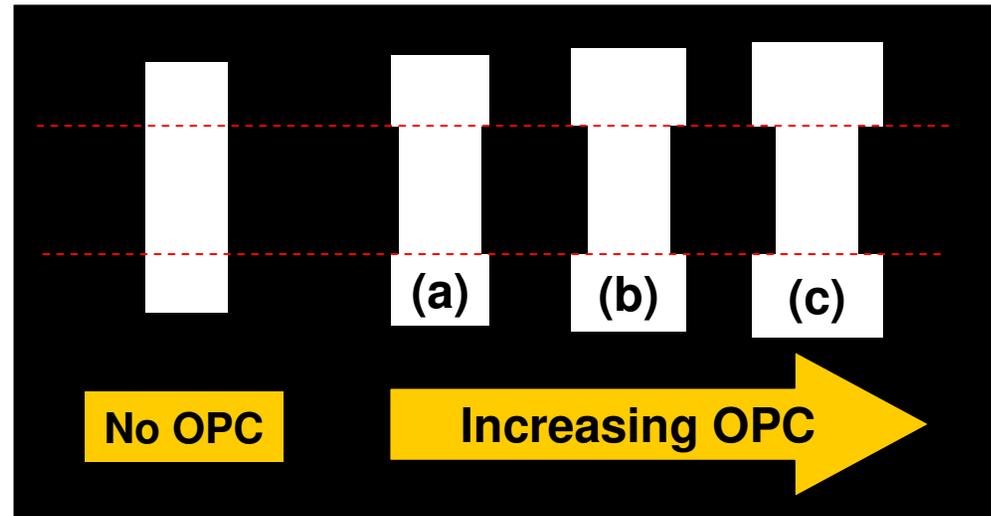
(a)



(b)



(c)



28 nm hp 4:1 trenches

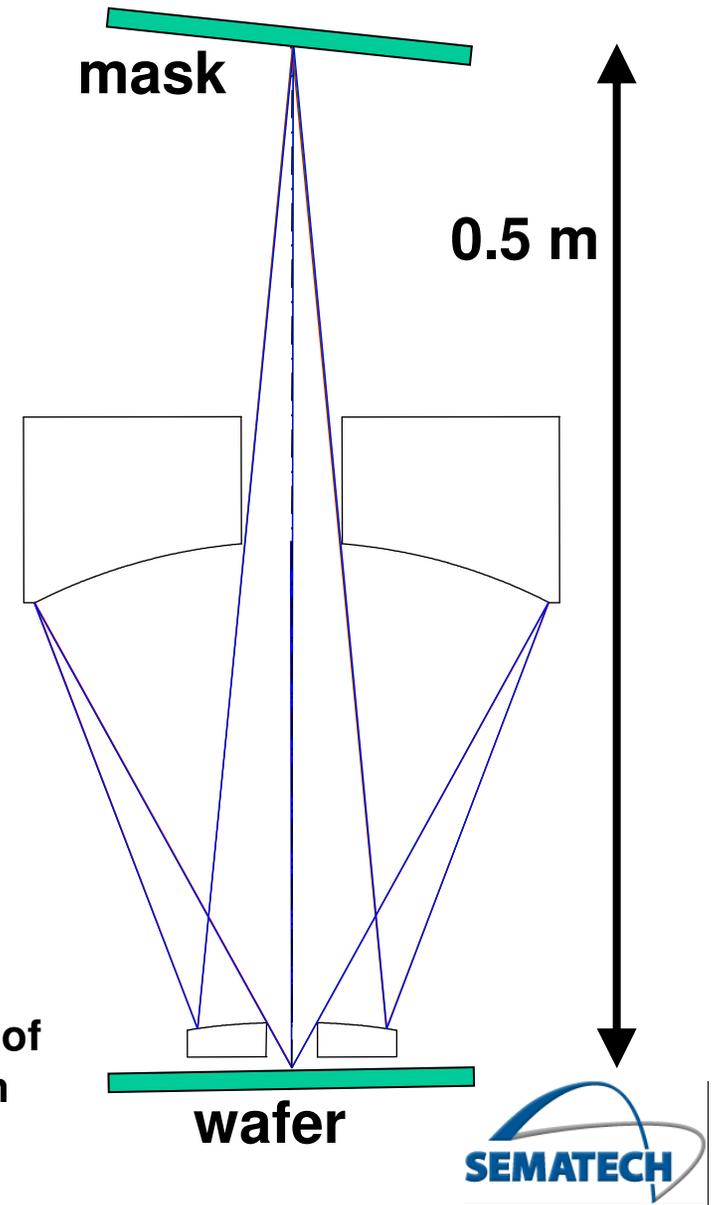
OPC	xCD 3 $\sigma$ (nm)	yCD 3 $\sigma$ (nm)	Area 3 $\sigma$ (nm <sup>2</sup> )
none	7.2	17	850
(a)	7.3	14	800
(b)	7.1	11	700
(c)	6.4	10	650



# ***Future plans: 0.5-NA SEMATECH MET in Berkeley***

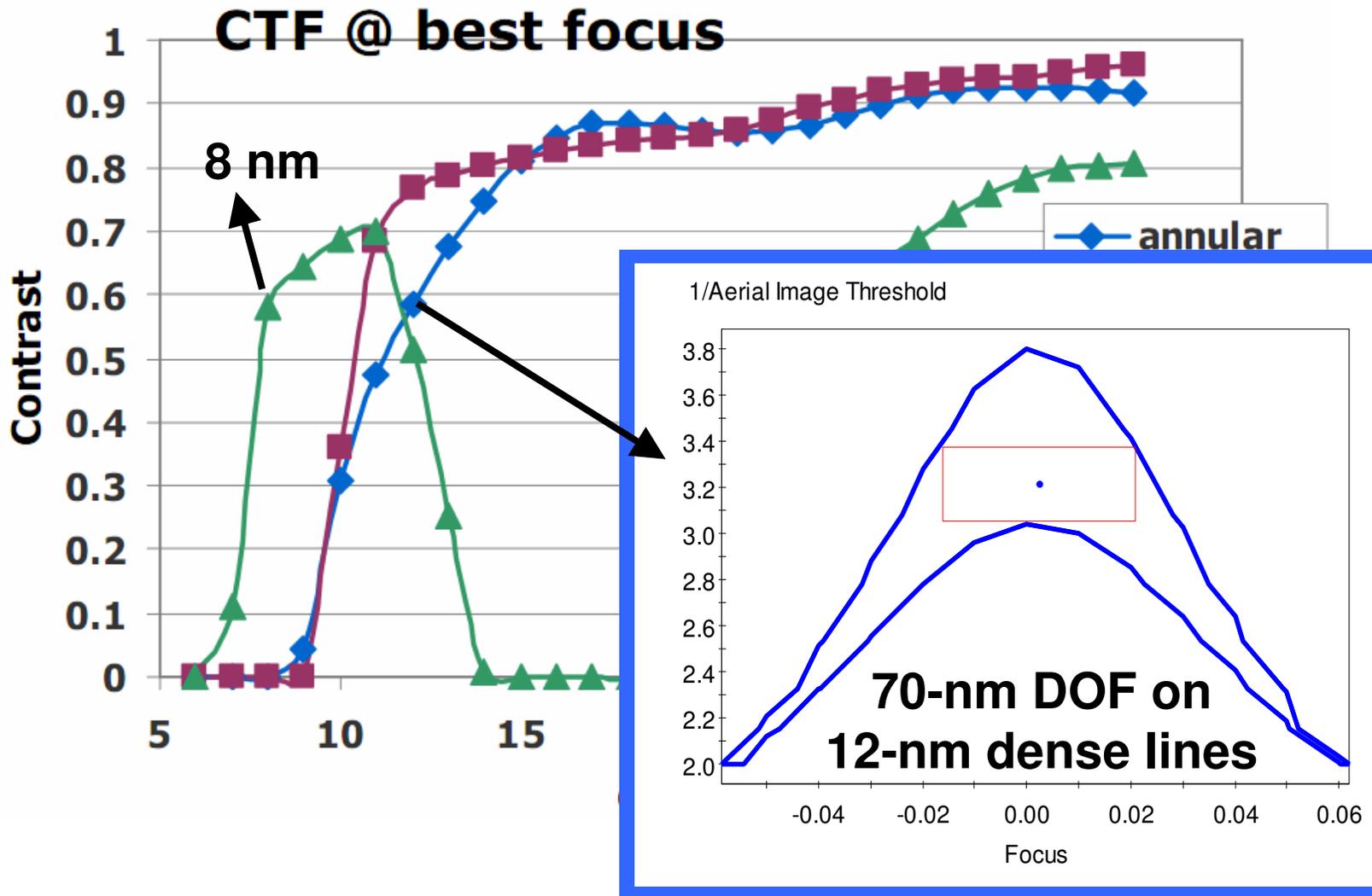


- Optic design complete and optics manufacturers engaged
- NA = 0.5
- Resolution = 8 nm
- Magnification = 5x
- Field of view = 200x30  $\mu\text{m}$
- Mask angle of incidence = 6°



Optical model courtesy of  
Russ Hudyma, Hyperion

# Sizable process windows for 12-nm features with conventional illumination



# Summary



- Champion resist improvement has stagnated over past year
- Sub-22-nm learning with current tools requires use of resolution enhancement techniques (RET)
  - Source optimization
  - Phase shift mask or equivalent
- Modulation down to 14-nm demonstrated with MET
- High coherence RET methods are very susceptible to mask phase roughness
- Planning underway for 0.5-NA microfield exposure tool supporting EUV R&D at 16-nm and well below



# ***Acknowledgments***



Erik Anderson  
David Attwood  
Kevin Bradley  
Rene Delano  
Jeff Gamsby  
Eric Gullikson  
Bob Gunion  
Drew Kemp  
Seno Rekawa  
Farhad Salmassi  
Ron Tackaberry  
***LBNL***

Shinji Tarutani  
***Fujifilm***  
  
Jim Thackeray  
Katherine Spear  
***Rohm and Haas***

Rick Uchida  
Yohei Kinoshita  
***TOK***

Harry Levinson  
Obert Wood  
***Global Foundries***

Bob Allen  
Greg Wallraff  
***IBM***

Ted Liang  
Guojing Zhang  
***Intel***

Seong-Sue Kim  
Hwan-Seok Seo  
***Samsung***

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